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This report describes the considerable improvements in surface physics instrumentation at the Plasma and Surface Physics Laboratory made possible by the DURIP Grant AFOSR-89-0195. The following three add-on instruments were purchased: Scanning Tunneling Microscope (STM), Low Energy Electron Diffractometer (LEED), Quadupole Mass Spectrometer (QMS). A unique design has been chosen for STM. Starting with a non-vacuum STM (Nanoscope II), a vacuum compatible STM head was designed. The head uses the Nanoscope computer and can be attached to either of our UHV chambers. All the acquired instruments have been integrated with the two surface instrumentation systems existing in the laboratory. The Surface Analysis System is equipped with Auger Electron Spectroscopy (AES), Ultra Violet Photoelectron Spectroscopy (UPS), Work Function Measuring Station and Sample Transfer System for the STM. The Ion Beam System is equipped with the Quadrupole Mass Spectrometer (used for Secondary Ion Mass Spectroscopy and Ion Scattering Spectroscopy), LEED, two Ion Beam Lines and Sample Transfer System for the STM.

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SURFACE PHYSICS INSTRUMENTATION

FINAL REPORT, GRANT AFOSR-89-0195

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DEPARTMENT OF PHYSICS AND ENGINEERING PHYSICS

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CONTENTS

1. INTRODUCTION

This report describes the considerable improvements in surface physics instrumentation at the Plasma and Surface Physics Laboratory made possible by the DOD Instrumentation Grant AfOSR-89-0195. The following three add-on instruments were purcased:

Scanning Tunneling Microscope (STM)
Low Energy Electron Diffractometer (LEED)
Quadrupole Mass Spectrometer.

After detailed studies a unique design has been chosen for the implementation of the STM. We have purchased the Nanoscope II which is the commercially most successful STM, but has a microscope head not compatible with vacuum operation. We have designed a vacuum compatible head that can be attached to either of our two UHV vacuum chambers. After sample transfer the microscope head is detached from the vacuum chamber, placed in a vibration isolation cabinet and connected to the Nanoscope computer. Good vacuum is provided by an ion pump that is permanently attached to the microscope head vacuum chamber. The construction of this new microscope system is in progress. Some of the components were purchased by Stevens Institute.

The instruments have been added on two surface instumentation systems existing in the laboratory. The Surface Analysis System is equipped with Auger Electron Spectroscopy (AES), Ultra Violet Photoelectron Spectroscopy (UPS), Work Function Measuring Station and Sample Transfer System for the STM. The Ion Beam System was built with funds provided by Stevens Institute, DOD Instrumentation Grant and using some available components. The system is equipped with the Quadrupole Mass Spectrometer (used for Secondary Ion Mass Spectroscopy and Ion Scattering Spectroscopy), LEED, two Ion Beam Lines and Sample Transfer System for the STM. These two systems provide very good tools for research in surface science.

2. LISTING OF INSTRUMENTS

2.1 INSTRUMENTS ACQUIRED WITH GRANT FUNDS

SCANNING TUNNELING MICROSCOPE (STM)

1. Digital Instruments Inc.	$66,500.00

complete NanoScope II (STM) system;
microscope with scan head
control electronics unit
computer work station
color monitor (VGA) for STM image
monochrome monitor for control
24 pins printer, mouse and software
all interconnectors
100 Nanotips
HOP graphite sample
high voltage option

2. MARVAC SCIENTIFIC	$1,535.00

6" gate valve UHV-4000-M

3. BALZERS	$7,790.00

TSU 170 turbomolecular pump stand including;
turbo pump, rotary roughing pump and
associated power supply - PM S02 282
splinter shield - PM 006 125X
emergency vent valve - TSF 012

4. DURAMIC PRODUCT INC.	$775.60

1.5" dia. machinable ceramic
1, 3/4, 1/2, and 1/4" dia. boron nitride

5. NOR-CAL PRODUCTS INC.	$2,804.00

STM chamber - custom order
2 transporting chamber - custom order
2 flat nipple for transporting line
2 con flat reduction tee
2 24" flexible bellows

6. MDC	$7,125.00

4 magnetic coupled sample transport
2 alignment gimbals
3 wobble stick
rotary-linear motion feed through
2 reduction flange

---------------------------------------Subtotal $86,529.60

QUADRUPOLE MASS SPECTROMETER

1. EXTREL CORPORATION		$39,668.00

EX 750 Quadrupole mass spectrometer system including;
Model 7-270-9 quadrupole mass analyzer
Model C50 control electronics:
electrometer/preamp
mass control unit: DC supply and 1.2 MHz 300 watt RF supply
SIMS upgrade to include model 616-2 bessel box
Bipolar multiplier supply
Counting preamp model 032-6
Coupling capacitor model 033-6
C50 display model U-873

--Subtotal $39,668.00

LOW ENERGY ELECTRON DIFFRACTOMETER

1. PRINCETON RESEARCH INSTRUMENTS INC. $17,900

RVL 8-120 electron optics for reverse view LEED

2. PERKIN-ELMER $6,237

Model #179233 PHI model 11-020 LEED electronics
Model 615421 Cable kit

--Subtotal $24,137.00

== Total $150,334.60

2.2 INSTRUMENTS PURCHASED BY STEVENS

STM

1. BURLEIGH INSTRUMENTS INC.	$1,500.00
micro-inchworm for coarse tip approach	
2. CERAMASEAL	$833.57
20-conductor feed through (2 3/4" C.F.) 10-conductor feed through (1 1/3" C.F.) pin connectors and ceramic spacer	
3. VAT INC.	$4006.00
5 mini UHV gate valves UHV angle valve and seal kit	
4. VARIAN ASSOCIATES	$3,914.75
ion pump - 30 l/sec. ion pump power control unit ion gauge	
5. LARSON ELECTRONIC GLASS	$345.00
3 zero length view port (2 3/4" C.F.) 2 zero length view port (1 1/3" C.F.)	
6. CONTROLLED ACOUSTICS CORP.	$413.10
sound insulation foam	
7. COMPUTOPIA	$427.00
80387 math coprocessor	
8. DIGITAL INSTRUMENTS INC.	$300.00
UHV scanning head	
9. STEELCASE	$2000.00
desk and chairs for STM system	
10. ANALOG DEVICES	$1,200.00
power supplies pre-amplifier and elctronic parts	
11. SET-UP	$1,000.00
---------------------------------------Subtotal	$15,939.42

ION BEAM SYSTEM

1. UHV INSTRUMENTS	$9,136.00

12" stainless steel spherical vacuum chamber
8" view port
6" full nipple
6" flexible coupling
6" radius elbow
blank flanges
flange bolts and gaskets

--Subtotal	$9,136.00
== Total	$25,075.42

2.3 AVAILABLE COMPONENTS

1. BASIC VACUUM COMPONENTS

   Perkin Elmer 270 l/s ion pump and power supply
   VAT Inc. 8" UHV gate vlave

2. SAMPLE MANIPULATION

   Huntington PM-600-XYZR precision manipulator
   sample holder
   sample electron beam heater
   sample insertion system with pumping (see section 2.1)
   faraday cup

3. LOW ENERGY ION BEAMLINE

   Kratos Mini-Beam I differential ion gun
   and power supply
   Wien filter ion mass seperator
   deceleration optics
   bessel box energy selector
   Power supplies and electronics

4. CESIUM ION GUNS

   Kratos Mini-Beam II
   Micro Beam
   Associated power supplies

5. SIGNAL PROCESSING

   Keithly 614 electrometer
   Oscilloscopes
   Power supplies
   X-Y recorders
   Multimeters

3. DESCRIPTION OF INSTRUMENTS

3.1 SCANNING TUNNELING MICROSCOPE

Scanning tunneling microscopy gives atomic resolution images of a sample surface using tunneling current between the scanning tip and sample. The determination of surface structure has been a major concern in the fields of condensed matter physics and chemistry. Since the STM was introduced by Binning, Rohrer, and co-workers in 1981, the STM has become a powerful new tool for examining surface details from the micron scale down to atomic resolution.

The STM can operate in air, vacuum, or under fluids. The Nanoscope II, which we purchased, is used for air or fluids. The system is shown in Fig.1. Since the resolution of the STM is less than an angstrom, special vibration isolation is required. The microscope is enclosed in a vibration-free microscope enclosure, which is surrounded by sound isolation foam. The microscope is placed on a platform which is suspended from the ceiling by rubber cords. The rubber cord suspension has proven to be one of the most effective ways to attenuate the vibration. Our measurements show that on the order of 50 dB vibration attenuation is achieved with this suspension. The Nanoscope II is digitally controlled, and instrumnet parameters are completely controlled with an IBM compatible PC and monochrome mobnitor. The image is viewed on a saparate image processing monitor (VGA) in real time.

ULTRA HIGH VACUUM (UHV) SCANNING TUNNELING MICROSCOPE

We are mainly concerned with UHV surface modifications. Rather than purchasing a commercial UHV STM, we decided to design and build our own unit which would match our existing UHV systems. We purchased the Nanoscope II unit primarily for its control electronics and data analysis software, which are considered among the best in the industry. Our UHV STM was designed to be compatible with these electronics. We designed a small movable STM chamber which can be placed directly in the vibration free cabinet. Samples can be modified in either of two UHV systems and transferred into the STM for analysis. This avoids having to vibration isolate the entire UHV system.

We designed a UHV sample transfer system to transport the sample from a UHV system to the STM chamber. This arrangement is shown on Fig.2. The sample transfer chamber is first evacuated by a turbo pump. The two gate valves shown in fig.2 may then be opened, allowing sample transfer. The sample is transferred between sections with magnectic coupled linear feedthroughs. After the sample has been positioned properly in the STM chamber, both gate valves are closed. The STM chamber is then disconnected and moved into the vibration free cabinet.

A schematic of the portable STM is shown in fig.3. The sample is placed on a base made of Macor machinable ceramic, which has a similar thermal expansion coefficient as the piezo ceramic scan head. This helps to eliminate thermal drift problems. The piezo tube scan head

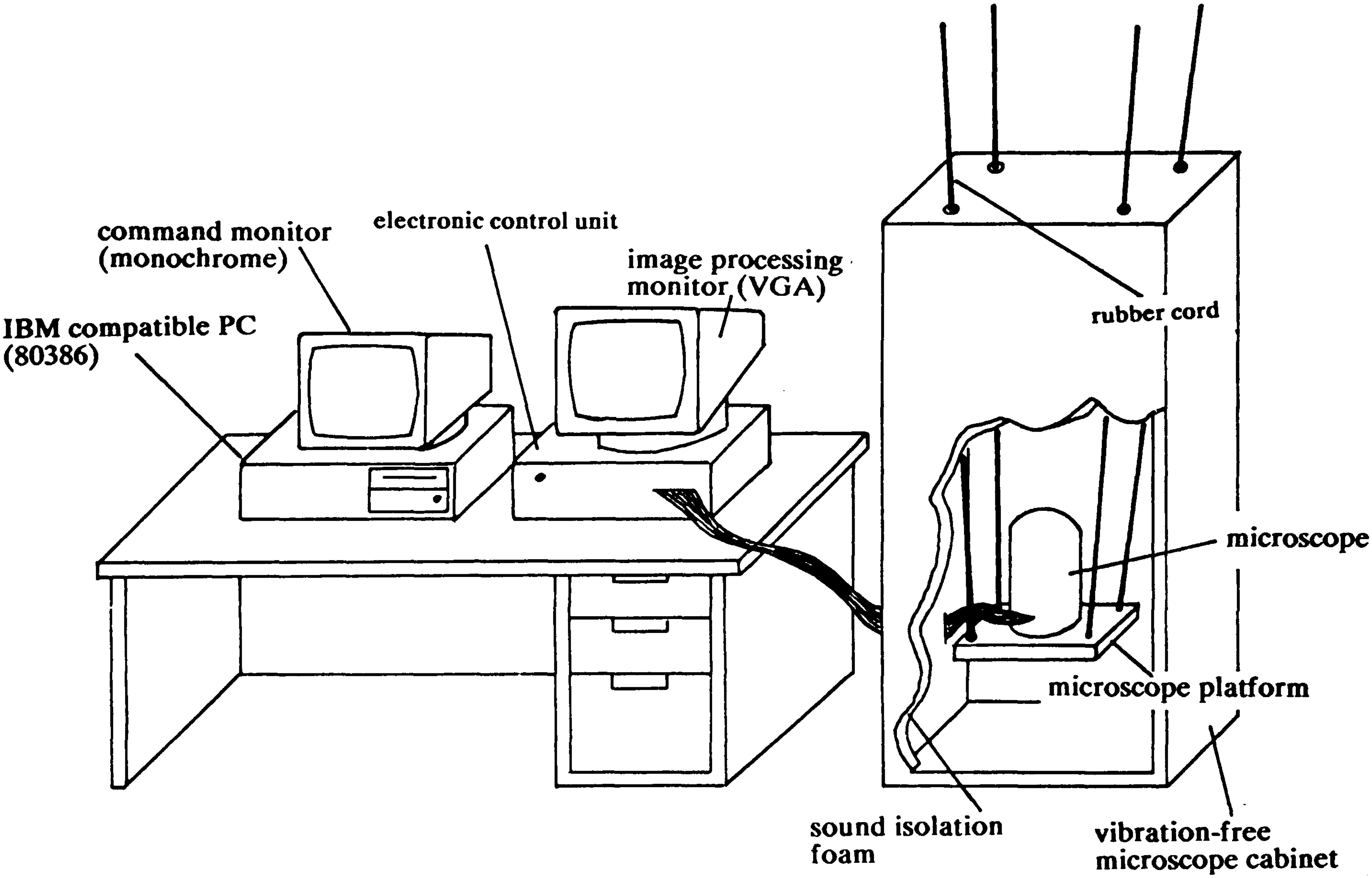


FIG.1. SCANNING TUNNELING MICROSCOPE (STM) SYSTEM

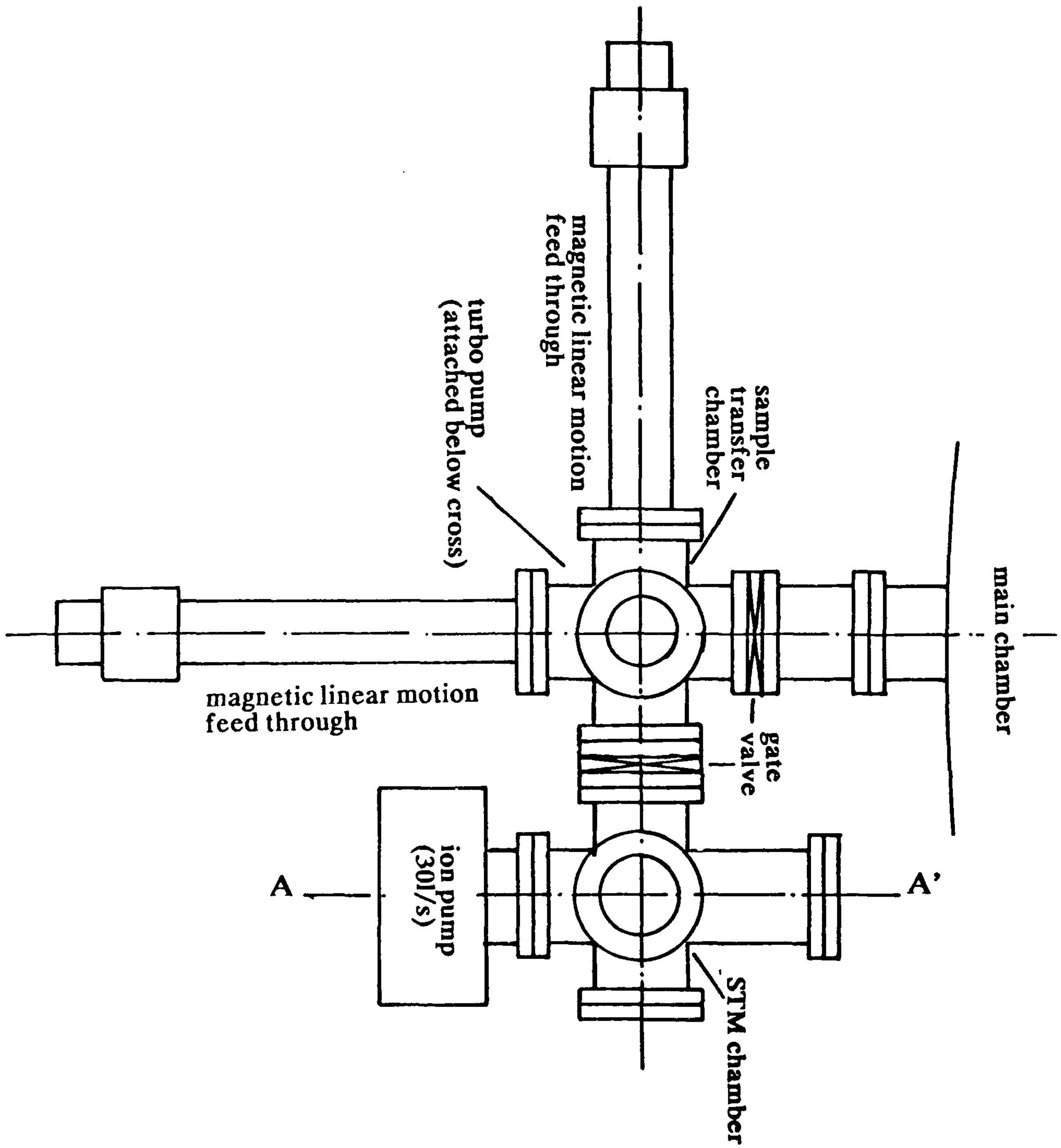


FIG.2. SAMPLE TRANSPORTATION SYSTEM

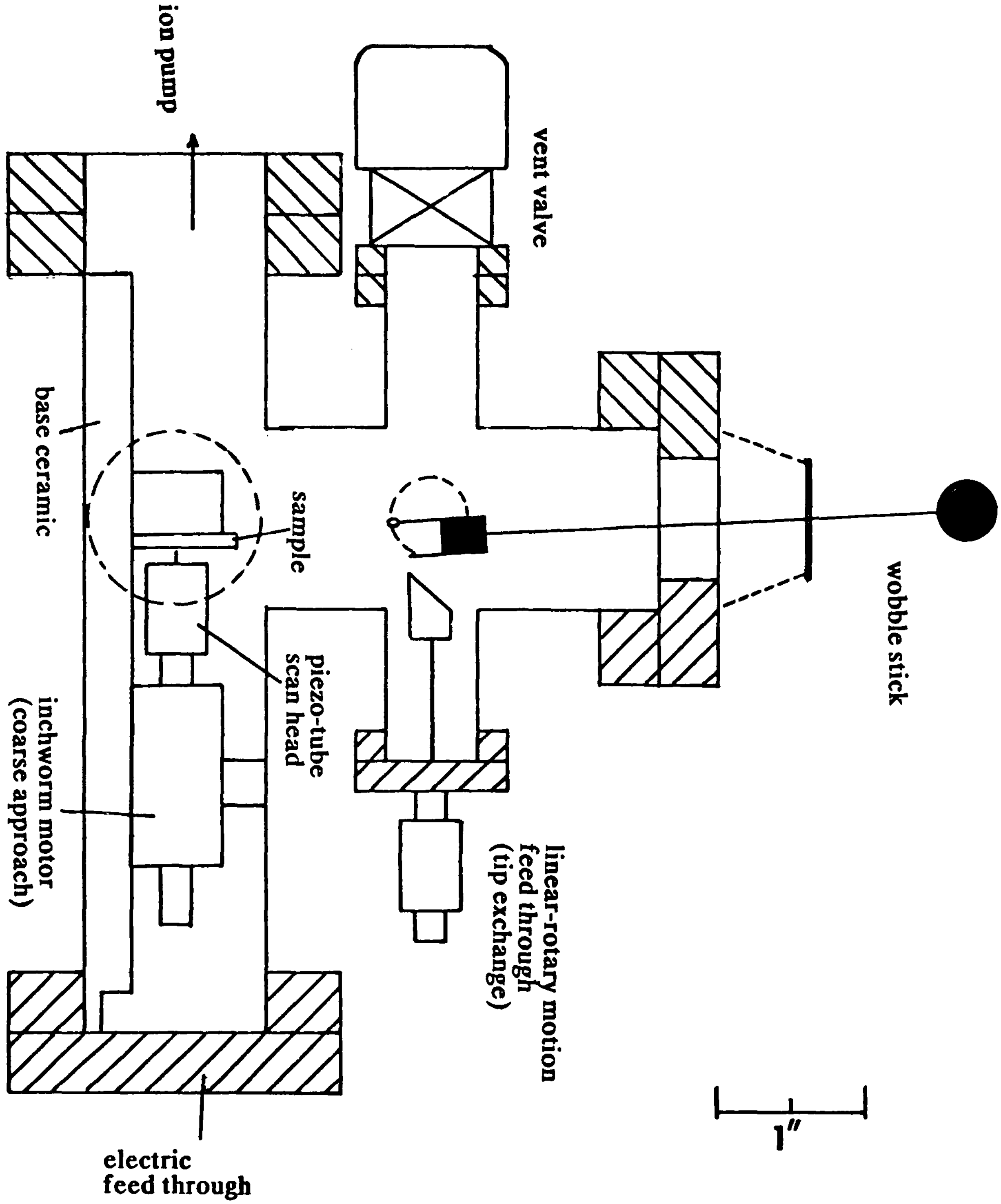


FIG.3. ULTRA HIGH VACUUM (UHV) SCANNING TUNNELING MICROSCOPE (STM)
(cross sectional view of A-A' on fig.2.)

is obtained from Digital Instruments Inc., and is capable of x, y, z motion. The maximum scan size is 0.84 μm on a side. First, the sample is placed within 2 mm of the scanning tip by using the wobble stick, and optical microscope which is attached to the front view port (not shown in fig.3). The tip is then moved by the UHV inchworm motor (Burleigh Inc.) until tunneling current is detected. At this point distance between the tip and sample is approximately 10 Å. The control electronics for this coarse approach is designed so that it may be interfaced directly to the Nanoscope II control unit. Using the z-axis feed back loop, the inchworm motor is stopped when tunneling current is detected. Image processing and spectroscopic studies are done with the Nanoscope II control unit in the same way as in air operation. If the scanning tip is damaged, tip exchange can be done in vacuum using the wobble stick and tip exchange station shown in fig.3. After STM studies, the sample can be transferred back to the main chamber by the reverse procedure to that described above.

3.2 QUADRUPOLE MASS SPECTROMETER

The EXTREL Quadrupole Mass Spectrometer system (Figure 4) provides chemical analysis in the range 1 - 2000 amu (atomic mass units) The system can operate in two modes: Secondary Ion Mass Spectroscopy (SIMS) and Residual Gass Analysis (RGA). In the SIMS mode, ions are sputtered from the sample surface by an ion gun and analyzed by the quadrupole. In SIMS mode either positive or negative ions can be detected. In RGA mode, residual gas molecules in the chamber are ionized by electron bombardment and analyzed by the quadrupole. The system consists of four main components: ionizer/extraction optics, quadrupole mass analyzer, multiplier and signal processor.

The ionizer/extraction optics either collects or creates ions depending on the mode of operation. In RGA mode, a hot filament produces electrons which are accelerated by a voltage between the filament and the ionizer wall. Residual gas molecules which collide with these electrons are ionized. A pair of extraction electrodes accelerate the ions towards the quadrupole mass analyzer. In SIMS mode, ions produced at the sample surface are accelerated towards the extraction optics by the front two electrodes. These ions are then subject to a retarding field bessel box analyzer which selects out ions in a narrow energy range. (typically 1-2 eV) before they enter the quadrupole. This is desirable because there is an optimum kinetic energy for maximum transmission through the quadrupole.

The quadrupole mass analyzer is constructed of four stainless steel cylindrical rods arranged in a square with their axes parallel. The axis through the center of the square parallel to the axes of the rods is known as the z-axis. Rods on diagonally opposite corners of the square are electrically connected. To one pair of rods a D.C. potential U and an rf potential V are applied. To the other pair of rods the same potential, but of opposite sign, is applied. An ion injected at one end of this assembly with motion generally paralell to the z-axis will undergo transverse motion due to the rf and dc fields which are perpendicular to the z-axis. For a given U and V the ion

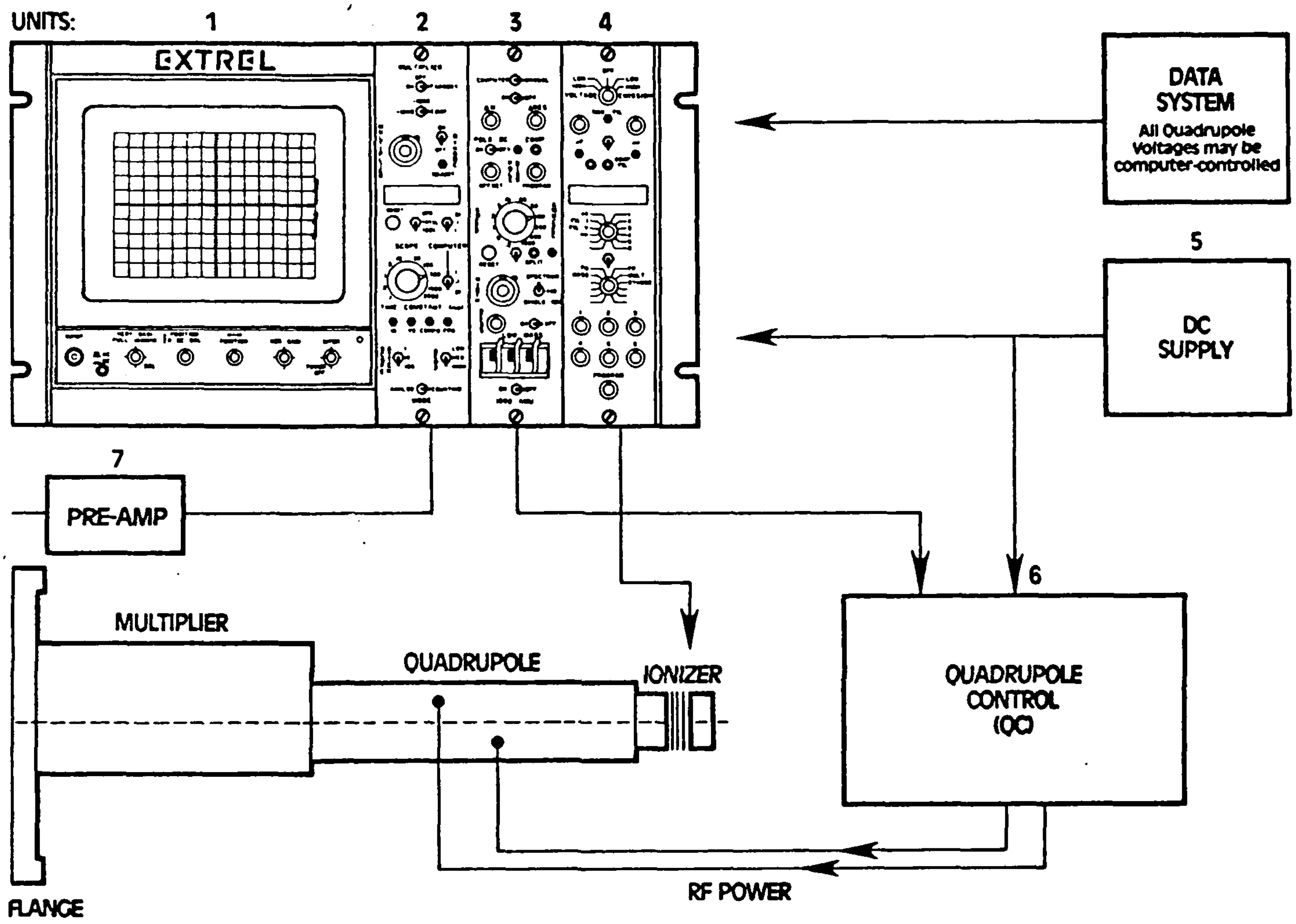


Figure 4

Quadrupole Mass Spectrometer System Schematic trajectories will be either stable or unstable depending on the value of m/e for the ion. Ions with unstable trajectories move away from the z axis and ultimately strike one of the rods, thus beinbg removed. Those with stable trajectories pass through the quadrupole to emerge at the opposite end and enter the multiplier.

Since the actual ion current is likely to be too small to be detected, a Channeltron electron multipler is used to increase the signal to a detectable level. The channeltron consists of a hollow tube which is funnel shaped at the input end. The inside surface is highly resistive. A high voltage is placed between the input end and the anode end. Ions are accelerated toward the funnel by the high voltage. When an ion electron or photon strikes the multiplier input secondary electrons are produced. These are accelerated towards the anode end by fields due to the potential difference between the two ends. The tube is curved so that electrons emitted at one point on the interior surface will most likely undergo a collision with the wall of the tube, thus producing more electrons. A single ion striking the Channeltron at its input produces a cascade of electrons which are collected at the anode. The ratio of electrons collected to incident ions is the gain. Typical gain for such a multiplier is of order 10^6-10^7.

Electrons collected at the anode of the multipler are read as a current which is the input for the signal processor. The signal processor consists of a preamp, electrometer, and display unit. There are two types of preamp; analog and pulse counting. In analog mode, the analog preamp amplifies the signal current and sends it to the electrometer which measures it and sends it to the display. The display signal can be used to determine an ion current. In the pulse counting mode the counting preamp detects each cascade or pulse of electrons from the multiplier and counts the number of pulses over a set counting time. The output from the counting preamp is proportional to the count rate. Since a single ion can trigger a pulse extremely low ion concentrations can be detected.

Actual performance of the quadrupole in both the SIMS and RGA modes has been exceptional. Mass resolution of one part in 600 has been observed in RGA tests and even higher resolution is claimed by the manufacturer. In SIMS mode clear mass spectra have been obtained for negative ions ranging from 1 to 90 amu.

3.3 LOW ENERGY ELECTRON DIFFRACTOMETER

GENERAL DESCRIPTION

The Princeton Research Instruments, Inc. (PRI) Reverse view LEED Optics unit (See Figure 5), consists of 4 nested hemispherical grids and a hemispherical glass collector screen, each of which has a central hole through wich the snout of the electron gun protrudes. The sample under investigation is positioned at the commom center of curvature of the grids and the collector screen and is usually perpendicular to the primary electron beem. To view the (00) or specularly reflected beam,

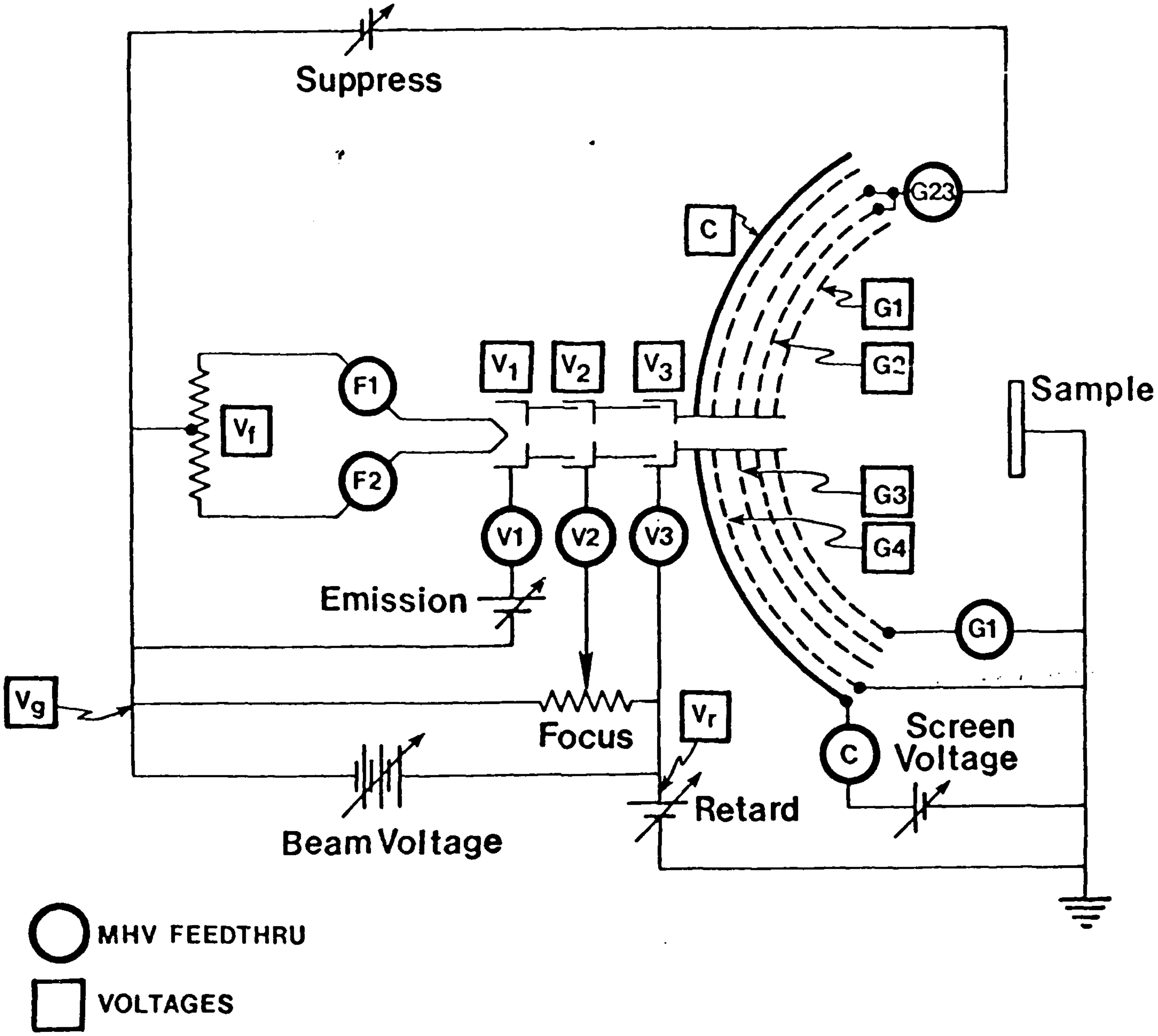


Figure 5

LEED System Schematic

the sample must be tilted slightly. The sample must be grounded, but its mount should be electrically isolated and brought out through the vacuum wall if beam current measurement with respect to ground is desired.

The first grid G1, nearest the sample, may be floated for special purposes but is most commonly grounded. The second and third grids, G2 and G3, are tied together internally and connected electrically through an MHV feedthru to the power supply. These two grids are known as the suppressor grids. The fourth grid G4, nearest the collector screen, is permanently grounded internally.

The collector screen, electrically connected through a feedthru, is coated with an optically trasnparent coating of tin oxide over which is applied a uniform layer of phosphorescent material. This powdery material is excited by the incoming electrons and emits visible light, like in an oscilloscope tube. To obtain sufficient efficiency in this process, the screen is biased at a potential of 2 to 5 kV.

PATTERN FORMATION

LEED patterns are obtained from the optics on the following manner:

a. A focused, fine spot, monoenergetic electron beam from the gun strikes the sample which must be atomically clean and ordered.

b. Diffracted beams emerge in various directions with various intensities from the sample and traverse the field free region between the sample and the grounded first grid G1. The locations and intensities of these various beams will vary with the energy of the primary electron beam.

c. Voltages are programmed on the inner grids G2 and G3 to allow only the diffracted electrons (which have sufficient energy by their nature) to pass through the grids and on to the grounded fourth grid G4. Varying the voltage on G2 and G3 thus provides a method of contrast adjustment In other words, the two inner grids act as a high pass filter. The use of double grids gives superior energy resolution over systems employing only one suppressor grid.

d. The electrons that pass through the grounded fourth grid are then accelerated by the potential on the collector screen. The grounded fourth grid acts as a shield between the two suppressor grids and the collector screen

e. The electrons thus accelerated strike the collector screen and cause phosphorescence which results in the visible LEED pattern.

In the PRI reverse view LEED optics this pattern is viewed from behind the collector screen through a viewport in the center of the mounting flange. It is obscured only by the shadow of the minature electron gun and thus allows the use of samples of unlimited size. The head on geometry is identical with that of most other surface analytical techniques.

4. DESCRIPTION OF SYSTEMS

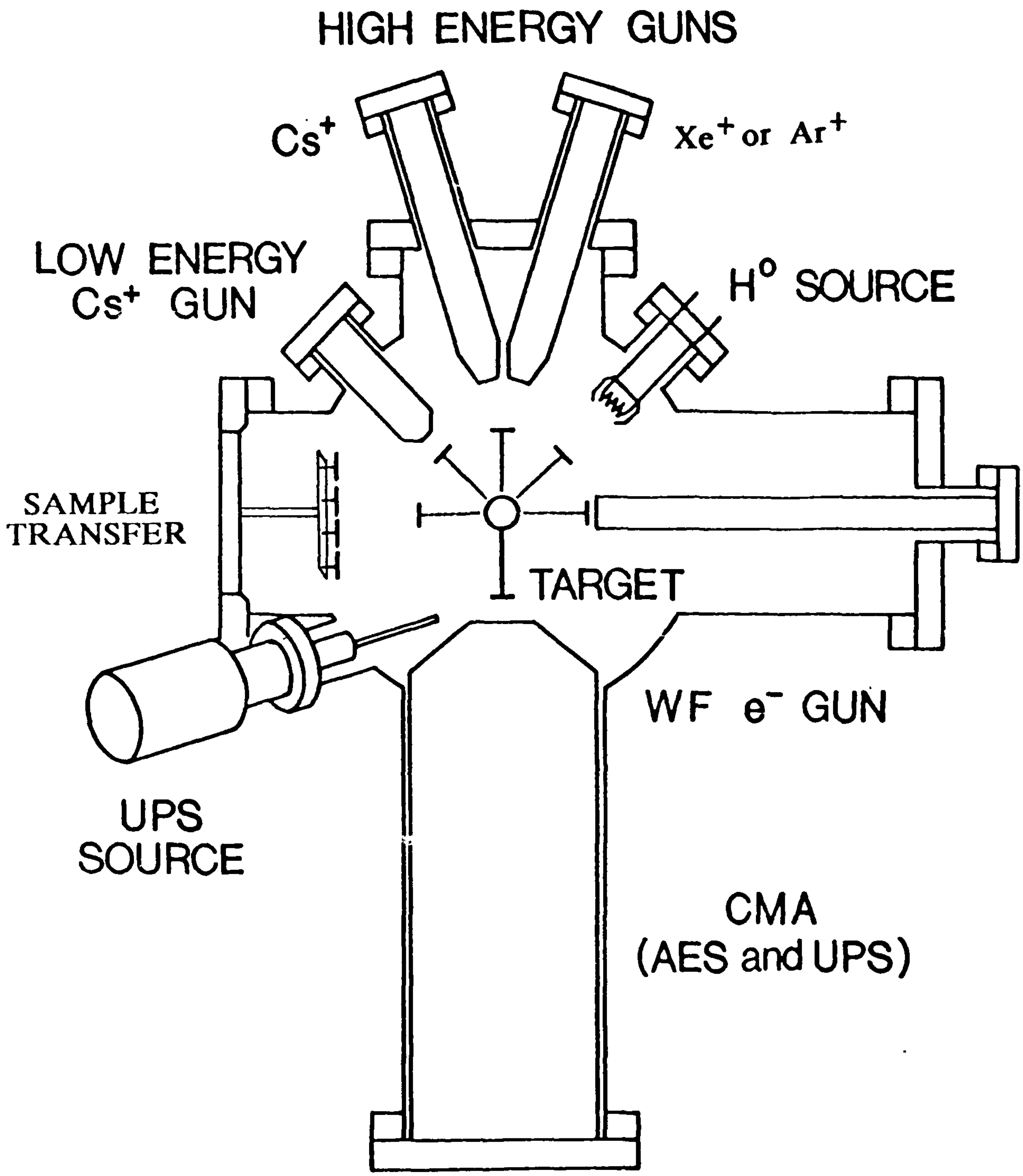
4.1 SURFACE ANALYSIS SYSTEM

This is a UHV system, with a base pressure of 3 x 10^{-11} torr. A system schematic is shown in figure 6. It is equipped with a high precision xyz manipulator, a sample transfer device, a double pass, angularly resolved cylindrical mirror analyzer (CMA), with a coaxial electron gun for Auger electron spectroscopy (AES), a helium discharge lamp for ultraviolet photoelectron spectroscopy (UPS), a hot filament for atomic hydrogen deposition, a low energy electron gun for work function shift measurements, a tunable light source and/or He-Ne laser for photoemission onset measurements, low and high energy cesium ion guns, and a noble gas ion gun with multiple gas inlets. Experimental control and data acquisition are accomplished with a microcomputer. We will now discuss the system in greater detail.

The sample is mounted on an xyz manipulator with both azimuthal rotation and sample tilt. It is also equipped for electron beam heating and liquid nitrogen cooling of the target. Sample temperatures of 150°K to 1300°K are achieved with this setup. Also mounted on the manipulator, is a shielded Faraday cup used for measurement of beam current and size, and also for beam alignment. A sample transfer mechanism was designed and installed which allows up to 4 samples to be stored in vacuum, and transfered on to, and off of, the manipulator. An improved version of this set-up is now being constructed, which will also allow samples to be taken in and out of the vacuum system without breaking vacuum. This sample transfer sub-system is an integral part of the in vacuum STM which is presently being constructed.

The CMA is used for energy analysis of charged particles, which in this case, are electrons. The electron gun used for AES analysis is located coaxially within the first stage of the CMA. AES spectra allow a determination of surface adsorbate species, both atomic and molecular. A helium discharge lamp is used for UPS analysis. It is differentially pumped, using two turbo pumps. This allows the discharge to be operated at high pressure while maintaining low pressure in the chamber. The discharge is operated in two different modes, He I ($h\nu$=21.2 eV), and He II ($h\nu$=40.8 eV). He II data allow us to examine the valence band density of states (DOS) up to 20 eV below the Fermi level due to a lower secondary electron background in the region of interest. The He I discharge has a much higher intensity, and hence a better signal to noise ratio. UPS is seen to be very surface sensitive, showing strong adsorbate induced features even when very little is detectable with the AES.

The electron gun used to measure work function shifts is a modified commercial gun, in which the original lens system has been removed, and replaced with a simple drift tube. The source consists of a custom fitted tungsten filament, and a Wehnelt lens. The tunable light source consists of a xenon arc lamp coupled to a quarter meter type monochrometer. It can be continuously tuned from 250 to 1000 nm (5.0 eV to 1.2 eV). In order to convert work function shifts into



EXPERIMENTAL SCHEMATIC

FIGURE 6

absolute work functions, the photoemission onset is measured. Alternately, a calibration point may be determined by using a 20 mW He-Ne laser (1.96 eV).

The cesium guns are of our own design, and are described in detail elsewhere [Ref. 2]. Two extraction geometries are used, covering the energy range of 5-5000 eV, providing up to several μA of current to the target. The noble gas ion gun is of the electron impact ionization type, and is differentially pumped. It has separate, bakeable UHV leak valves, for the introduction of research purity xenon and argon.

All data collection and experimental control are accomplished using an AT&T microcomputer (IBM-AT compatible), which is equipped with an A to D converter, and an IEEE-488 bus controller. All of the software is developed in house, using compiled BASIC.

This system provides an excellent base for studies of surface modification, both chemical and electronic, by ion beams and surface adsorbates. A selection of the recent publications making use of this system is listed below.

[1] A.E. Souzis, H. Huang, W.E. Carr and M. Seidl, Submitted to J. Appl. Phys., Jan. 1990, Ms.# R-6468

[2] A.E. Souzis, W.E. Carr, S.I. Kim and M. Seidl, Rev. Sci. Instrum., (to be published Feb. 1990)

[3] A.E. Souzis, M. Seidl, W.E. Carr and H. Huang, J. Vac. Sci. Technol. A 7, 720 (1989)

[4] W. Carr, M. Seidl, G.S. Tompa and A. Souzis, J. Vac. Sci. Technol. A 5, 1250 (1987)

[5] G.S. Tompa, W.E. Carr and M. Seidl, Surface Sci. 198, 431 (1988)

4.2 ION BEAM SYSTEM

ION BEAM CHAMBER

The ion beam system is housed in the 12" diameter UHV spherical chamber. Because of the geometry of the chamber all experimental ports point to the center of the chamber. One of these ports is dedicated to sample transfer to the STM.

The chamber is evacuated in two stages. The first stage evacuation is through the Balzers 170 l/s tubo pump backed up by a two stage rotary pump. Chamber pressures of order 10^{-8} torr are achieved in this stage after about six hours pumping from atmosphere. The second stage pumping is done by the Perkin-Elmer 270 l/s ion pump which takes the chamber to 10^{-10} torr. Both pumps are isolated from the chamber (and each other) by UHV gate valves. All ports are fitted with conflat flanges and sealed with copper gaskets. The chamber is wrapped with heating tapes, covered with aluminum for bake out.

A manipulator mounted on a flange at the top of the chamber provides for linear motion along the X, Y and Z axes as well as rotation about the Z axis. The sample holder is mounted on a bracket attached to a rod which extends downward from the manipulator. The sample holder is designed such that the sample can be floated or externally grounded. An electron beam heater for annealing and cleaning the sample is built into the sample holder. The sample holder is compatible with the transfer mechanism to the STM. A faraday cup for beam measurement is mounted just above the sample holder.

The four principle instruments are mounted on flanges on the equator of the ion beam chamber (See figure 7):

1) Low Energy Ion Beam Line
2) Quadrupole Mass Spectrometer
3) Cesium ion guns
4) LEED

The Quadrupole and LEED have been described in sections 3.2 and 3.3 respectively. The Low Energy Ion Beamline is used in the ion reflection experiment.

ION REFLECTION EXPERIMENT

This experiment is designed to measure the energy dependence of the efficiency with which low energy portions are converted to negative ions at converter surfaces. Previous reflection experiments have examined thermal (<0.3 eV) and high energy (>100 eV) ions. The intermediate region has not been explored due to the difficulty of producing an ion beam with sufficiently high current in the 1-100 eV energy range. The ion beamline developed in this lab can produce a beam of hydrogen ions with energies as low as 10 volts.

Ion Beam Chamber

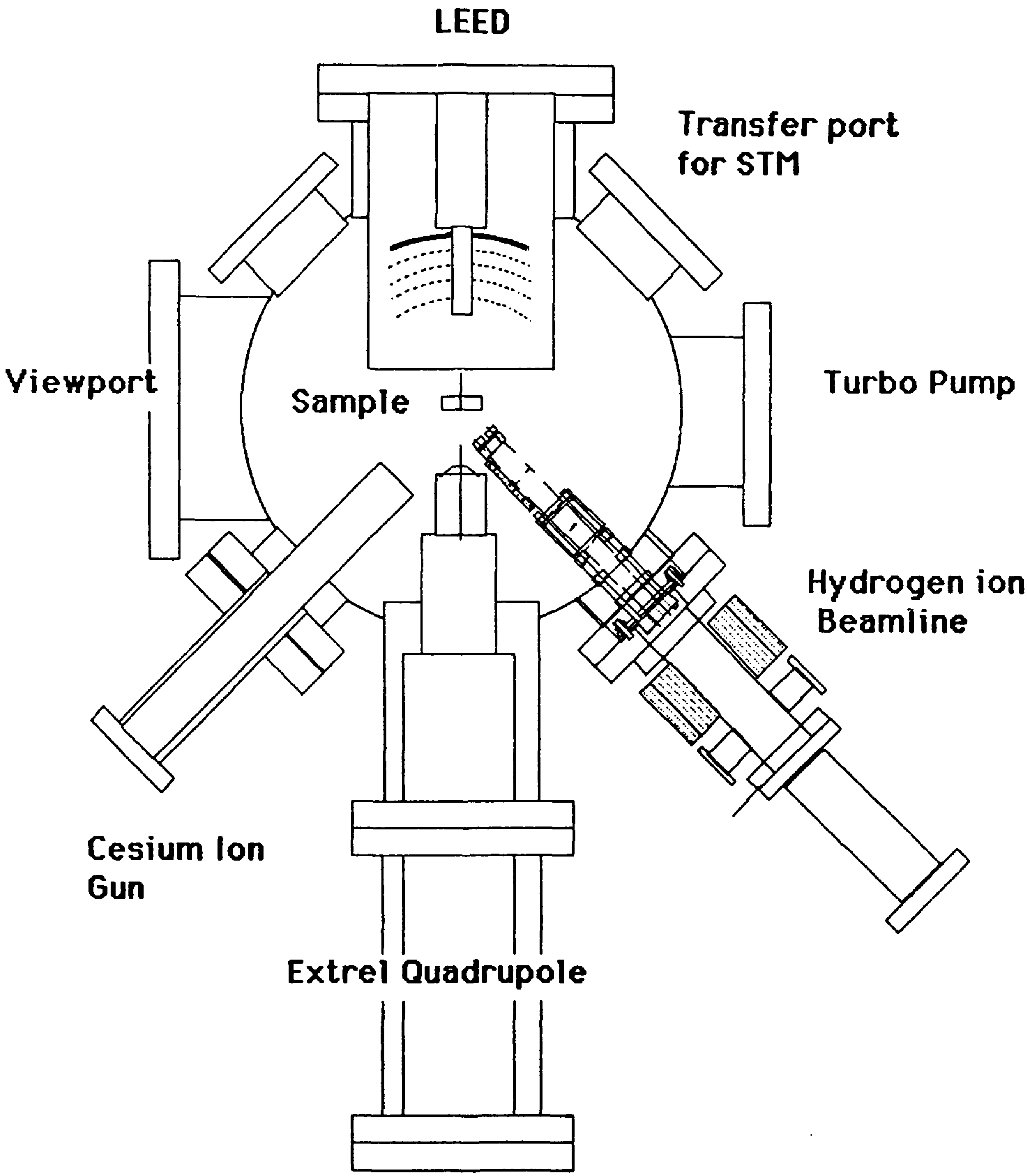


Figure 7

Positive hydrogen ions are produced by gas discharge in the Kratos Mini Beam I differential ion gun and accelerated to about 500 volts. It has been determined that three species of hydrogen ions are produced: H^+, H_2^+, H_3^+. It is necessary to select one of the species for further use. This is achieved by use of crossed electric and magnetic fields in the Wien filter. Ions of a given energy entering such a filter will pass through it undeflected only if they have the correct mass.

Ions which pass the Wien filter will then be decelerated by a series of electrodes to the desired energy. Because of the energy spread in the ions produced by the source it is necessary to utilize an energy filter to select out ions of the right energy. For this a Bessel Box energy analyzer which makes use of retarding electric fields was designed and built.

Ions which pass the Bessel Box are then focused onto the sample where some fraction of them are converted by resonant charge exchange into negative ions. These negative ions are then accelerated toward the quadrupole mass analyzer by means of extraction electrodes. The ions which pass through the quadrupole strike the mulitplier which produces a signal current proportiontial to the flux of negative ions. This signal can be used to determine the actual flux. When this is compared to the incident positive ion flux the negative ion yield can be determined.

CESIUM ION GUNS

The two Cesium ion guns provide focused beams with ion energies in the range 500-5000 eV. The mini beam gun produces a 1 microamp beam with a beam diameter of 1mm. This gun is used for in situ sample preparation.

The micro beam gun produces a beam current of 10 nanoamps with a beam diameter of 1 micron. This beam will be used for Scanning Secondary Ion Mass Spectroscopy (SIMS) in conjunction with the Quadrupole Mass Spectrometer. Elemental analysis in three spatial dimensions and with high sensitivity will be possible. The microbeam gun will be also used for studies in maskless ion beam microlitography.

5. USE OF EQUIPMENT

The acquired instrumentation is being used in the Plasma and Surface Physics Laboratory for studying the surface electronic structure of metal and semiconductor surfaces either clean or with specific adsorbates, electron transfer reactions in atom-surface interactions, and effects of catalysts on thin film formation. Part of this research is supported by the grant AFOSR-89-0019 "Surface Production of Ions" Milos Seidl, Principal Investigator. We have collaboration with the theoretical group of Walter Ermler of the Chemistry Department which is supported by the grant AFOSR 86N P309 "Theoretical Studies of the Electronic Structure of Metal-Semiconductor-Hydrogen Systems".

The research currently supported by AFOSR consists of experimental and theoretical studies of processes leading to the production of negative hydrogen ions on solid surfaces. The correlation between the surface electronic structure and ionization probability is being studied. The objective is to develop quantitative models for assessing the effectiveness and limitations of surface production of negative hydrogen ions for exoatmospheric applications. Electron tunneling between the substrate and the hydrogen atom moving away from the substrate's surface is the basic process in surface ionization. Since the Scanning Tunneling Microscope is also based on electron tunneling, it is an important tool in the search for substrates displaying high surface ionization efficiency. The Quadrupole Mass Spectrometer will be used as a mass- and energy-sensitive detector of negative hydrogen ions produced in atomic scattering from surfaces.

Another line of research actively pursued in this laboratory is thin film formation catalyzed by cesium deposited from vapor phase or by cesium ion bombardment. The Scanning Tunneling Microscope will be an important tool in studying the early stages of this process. So far we have studied catalytic oxidation of silicon by cesium ion bombardment and oxygen gas exposure at room temperature. Deposition of opaque carbon containing thin films by chemical vapor deposition stimulated by cesium ion bombardment has been investigated. It is planned to study cesium ion assisted CVD of several other technologically important thin films. The combination of this technique with the microbeam cesium ion gun will enable maskless ion beam deposition of patterned tin films on micron and submicron scale.

The new surface physics instrumentation has significantly improved the capabilities of this laboratory.